Metal Casting: Properties Measurement, Modeling, and Validation

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Abstract

Recent advances in the area of solidification modeling have brought these techniques to the point where it is very advantageous to be able to use a model to simulate and optimize processes such as casting, welding , and semi-solid forming. However, it has been recognized and documented in sources such as ASM International's "Advanced Materials and Processes" and "A Vision of the Future of the U. S. Metalcasting Industry" that there is a lack of thermophysical property data for metals near and extending into the molten region. Advances in the area of process modeling are limited by this shortage of data. Depending on the process, today's modelers and designers require many thermophysical properties as a function of temperature including density, thermal expansion, specific heat capacity, thermal diffusivity and conductivity, melting temperature, heat of fusion, emissivity, viscosity, and surface tension.

The Physical Properties User Center (PPUC) of the High Temperature Materials Laboratory (HTML) located at the Oak Ridge National Laboratory (ORNL) has existing capabilities which can and have been used to determine many of the thermophysical properties required as input to current solidification process models. These capabilities include a high temperature Differential Scanning Calorimeter (DSC), dilatometer, and Laser Flash Thermal Diffusivity system. The DSC operates to 1500°C and has been used to determine specific heat capacity (C_p), liquidus and solidus temperatures, and latent heat of fusion. The dilatometer operates to 1600°C and has been used to determine the thermal expansion and density of molten, as well as solid, metals using specially designed sample containers. The LFTD system has an operating range of -150° to 2400°C and can be used to measure the diffusivity of molten metals up to 1700°C, again using specially designed sample containers.

Examples of recent projects which utilized the PPUC capabilities to determine thermophysical properties for use in solidification process models are presented and include casting of a nickel-aluminum-bronze impeller, casting of aluminum-silicon alloys, and casting of a nickel aluminide (Ni_3Al) heat treating tray.

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